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NIAR is a Non-Profit, Non-Government Voluntary Organization emphasizing on encouraging peoples' participation in communication and information technology through Amateur Radio and disaster management.

OUR VISION

To build a world-class institution to support advancement of global Amateur Radio activity in terms of promotion, training, advocacy, technical support, knowledge repository and research, exceed the expectations with commitment, quality and excellent service.

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- Training / Awareness
- Disaster Management
- Support for Organisations
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- QSL Bureau
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Asia Pacific Jamboree of Scouts & Guides

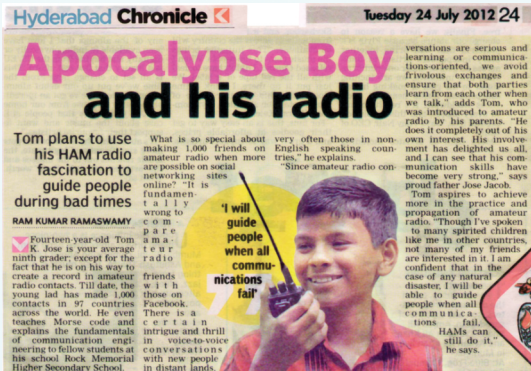


The 8th Asia Pacific Regional Air / Internet Jamboree held during 4th & 5th August 2012 was actively participated by members of AP State Scouts and Guides from the club station at NIAR, Hyderabad. Over 146 Scouts & Guides from various schools under the leadership of Ms. P. Bhagyalakshmi, S.O.C.(G) and Ms. G. Anantha lakshmi, JT.S.O.C.(G) attended the two day event.

Two-way amateur radio contacts were made on 20 M band and Echolink with other Scouts & Guides stations from New Delhi HQ, Noida, Pachmari etc. Ms.Geetha Rawat Joint Director BS&G NHQ NTC operating from VU2BSG conveyed Friendship Day wishes to A.P Scouts & Guides SOC (G) & (S). The fun filled interaction among participants with members from other

regions, had exchange of greetings commemo- rating Friendship Day and Songs in different languages with Students from KVS Tagore Garden, New Delhi and KVT Govt. High School students Pachmari and other local schools of Pachmari. Scout members and hams Mr.Sunil Choudary, U.P.Sri.S.P.Sharma DTC(S) interacted with students from their stations.

Special thanks to Smt. Shalini Misra, IAS, State Chief Commissioner BSG for encouraging and supporting their members to participate in this program. Mr.S.Ram Mohan, VU2MYH gave a brief introduction to amateur radio and Jamboree On The Air (JOTA) program. A video presentation on amateur radio was also shown, several participants expressed keen interest for attending a 15 day ham radio training program.



On 9th Aug 2012, a demo program on Disaster Management given for Bharat Scouts & Guides, Noida with Call sign of YL Machamma VU3HVC operated by OM Mukesh, VU2MCW. NIAR members supported the event from VU2NRO club station.



This article will focus primarily on the design of the receiver side of several modern high-performance amateur transceivers. There are other HF transceivers available, designed for commercial and government application where the customer can afford a higher price than an individual consumer. Delivering high performance while meeting a consumer price point adds additional challenges to the design task.

As with most systems, the first thing to do is define the worst-case system performance requirements. For high-performance receivers, the salient specifications are sensitivity (ability to hear weak signals), selectivity (ability to reject unwanted signals), and various ways of specifying the overall linearity of the signal chain. Linearity is important because any nonlinear stages that receive multiple signals (or even one single large signal) will cause artifacts that are indistinguishable from real signals. And like audiophiles, connoisseurs of radio performance (radiophiles?) have certain test cases and on-the-air circumstances that they use to determine a radio's real performance.

Sensitivity is actually the easiest specification to accomplish. It is relatively easy to design a receiver for the HF spectrum (3-30MHz) with sufficiently low noise figure that the system noise floor is set by atmospheric noise, not receiver noise. The generally-accepted test for an amateur receiver's Minimum Discernible Signal (MDS) is to determine the input RF level that raises the audio output in a narrow bandwidth (500Hz or so) by 3 dB compared to no input signal. Most modern receivers exhibit MDS on the order of -135 dBm.

Amateur radio is one of the few licensed HF radio services that does not use specified discrete channels (the recently-assigned 60-meter band is the only amateur band that uses fixed channels). In any given band, stations are free to use any frequency that is not in use by another station. Signal spacing can be surprisingly small. Consider the spectrum photo in Figure 1. This shows seven separate CW Morse-code signals in a 2kHz bandwidth (less than the width of one typical single-sideband voice signal).

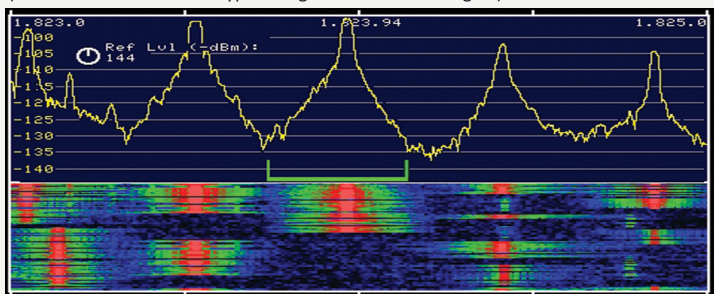


Figure 1: The top half of this photo shows seven CW signals in this spectrum analyzer display occupying less bandwidth than one single-sideband voice signal—the bottom half is a scrolling "waterfall" display of the same signals.

Selectivity can be achieved by analog filtering (usually multipole crystal lattice filters), DSP, or a combination of the two. The optimum tradeoff of analog/digital filtering, and where in the signal path it is applied, is an ongoing cost/performance compromise that changes with each generation of radio design...just like any other systems.

Linearity is the difficult specification. It determines how well a radio performs in the presence of other nearby signals. Various test methods are used to determine a radio's performance, and even constructing a decent test setup for the desired test condition is challenging.

In a receiver with linearity problems, spurious signals can result if the input signals are large enough. For example, the signals at 1823.5kHz (f1) and 1824.0kHz (f2) might produce a 3rd-order intermodulation product at 2f1—f2 or 1823kHz, well within the passband. No amount of filtering can eliminate this signal once it has been generated, since subsequent stages have no way of differentiating it from a real signal.

The problem is exacerbated when a large number of signals impinge on the front end of the receiver. In Figure 2, a 50kHz slice of spectrum is shown during a popular operating event.

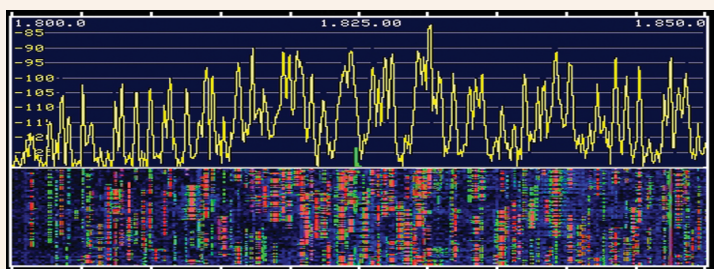


Figure 2: This display, captured during a popular on-the-air competition shows over 100 different signals sharing a 50kHz bandwidth.

Designing to the Test

Over the past decade or so, independent published reviews of transceiver performance have become increasingly important to the buying decision. There are two primary U.S.-based review sources. The first is QST magazine, published by the American Radio Relay

League (ARRL, www.arrl.org). The test methods used in QST Product Reviews have evolved to add new tests from time to time that improve the ability to evaluate radio performance, and include a comparison of the manufacturer's claimed specifications and actual lab measurements.

Another highly-regarded source for product reviews is Sherwood Engineering. The proprietor, Rob Sherwood, has been testing receivers for several decades, and offers aftermarket filter kits to improve receiver performance.

When a new transceiver comes to market, Sherwood conducts a thorough evaluation and adds the measured performance to a table listing nearly every high-end receiver he has ever tested. Radios that test at the top of the Sherwood list (which is sorted by the results of a close-spaced intermodulation test) and the QST review, can make the claim that their receiver is The Highest Performing.

At the time of this writing, the Yaesu FTD5000D and Elecraft K3 top the list, with the Yaesu radio demonstrating higher Third-order Intercept (IP3) in the ARRL's tests. In fact, both receivers tested so well in the close-spaced dynamic-range test that the measurements were phase-noise-limited (and these radios have low phase noise!).

The reason that these receivers achieve such high numbers, compared to previous generations of high-end radios is driven by the changing test methods and emphasis on a different performance specification. In the past, intermod testing was done at relatively wide signal spacing—typically 20kHz. This meant that the first IF filter could be 5kHz or 10kHz wide, and still do a good job of preventing signals 20kHz and 40kHz removed from the desired signal from encountering an amplifier or second mixer that might introduce nonlinearity. Many manufacturers adopted an upconverting architecture with a first IF above the carrier frequency, allowing for cheaper, smaller filters, and easier all-band coverage.

However, as the performance tests evolved to use tighter spacing of the two test signals (2kHz), many receivers using modest filtering at the first (upconverted) IF exhibited quite poor performance, since both signals passed through the wide filter and went through imperfect gain and mixing stages. Some manufacturers reverted to using lower IF frequencies and began to use narrower "roofing" filters that had become available in the first IF. For example, the Yaesu radio includes a 300Hz filter in the 9MHz IF stage. Combined with a front-end designed for good linearity in the presence of large signals, the intermodulation dynamic range measurement was outside the ARRL's normal test range and became phase-noise limited.

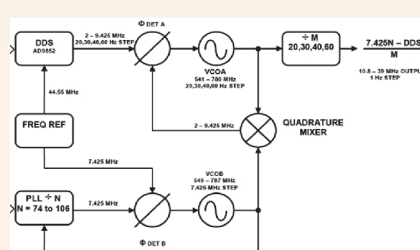
In the calculated IP3 test, the Yaesu receiver also went off the ARRL's charts with +41 and +40dBm at 20kHz and 2kHz, respectively (the Elecraft radio achieved +29 and +28 dBm).

The test method for this "intermodulation dynamic range" is to tune the receiver to the frequency of the expected intermodulation product and introduce the two interferers as carriers spaced 2kHz apart and increase their amplitude until the audio output level rises 3 dB above the noise floor. The IMD blocking figure is the difference between the input level and the MDS, and is typically close to 100 dB for high-performance receivers.

Another hard-to-meet specification

In a superheterodyne receiver, the incoming RF signal is mixed with a tunable local oscillator (LO) to move the desired signal to the IF stage where it can be filtered and amplified. Local oscillators are imperfect, and produce a signal at the desired frequency plus noise spread out on each side. The mechanisms that create these noise sidebands are well documented and depend on the oscillator design, whether a simple LC-tuned circuit or a design based on a phase-locked-loop (PLL) or direct-digital-synthesis (DDS). In PLLs, the loop bandwidth shapes the phase noise, and is a tradeoff of settling time and step size. The effect of LO phase noise in a radio receiver is often referred to as "reciprocal mixing noise", and is tested by applying a very pure stable CW signal to the receiver under test, and tuning away from the signal and observing the rise in the noise. In principle, the noise of the LO is downconverted and detected in the same way an input signal with noisy sidebands would be detected if the LO were perfect.

Early receivers used analog L-C oscillators to produce the tunable LO, sometimes combined with a set of fixed-frequency heterodyne oscillators to extend the range. PLL technology implemented with discrete components became popular in the 1970s, with multiple iterations before manufacturers tamed the phase noise.



As DDS became popular in the 1990s, transceiver manufacturers adopted it as a way of generating an LO with lower phase noise. And finally, as both PLL and DDS ICs improved in performance and integration, novel approaches combining the two have produced excellent results. In order to reach the highest possible performance for this application, most

transceiver designers have used integrated PLL and DDS chips but enhanced them with external components and using the chips well below their maximum rated frequencies.

The Ten-Tec Orion series of transceivers uses such a combination of PLL and DDS technologies to achieve extremely high performance. The block diagram is shown in Figure 3.

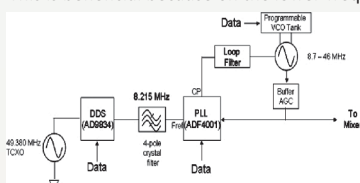
Figure 3: The LO synthesizer in the TenTec Orion series of transceiver uses a pair of UHF VCOs and dividers combined with both PLL and DDS technology to achieve extremely low close-in phase noise.

The LO tunes from 10.8 to 39MHz in 1Hz steps for high-side injection to the mixer, producing a 9MHz IF output when tuning the HF spectrum from 1.8 to 30MHz. There are actually two PLL loops in operation. A stable TCXO and divider generates two fixed outputs at 44.55MHz and 7.425MHz. The 7.425MHz signal is the reference frequency for a coarse PLL/VCO that generates an output tuned from 549 to 787MHz in 7.425MHz steps.

The 44.55MHz signal is used as the reference for the DDS, which produces an output that is tuned from 2 to 9.425MHz in 20, 30, 40, or 60Hz steps and becomes the reference for a phase-locked loop with a VCO that tunes from 541 to 780MHz in the same 20, 30, 40, or 60Hz steps. This signal is mixed down using the first PLL's output as an LO, and the downconverted signal is phase locked to the DDS output.

The VCO output is also divided by 20, 30, 40 or 60, yielding the necessary output range and 1Hz tuning step size for each band. The DDS chip in this circuit is specified up to a 300MHz output frequency, but is operated at much lower frequencies, since the spurious outputs were judged too high above 10MHz and would have caused artifacts in the LO circuitry.

This design achieves very low phase noise, on the order of 130dBc/Hz at small frequency offsets. An interesting side effect of this architecture is that the phase noise at any given offset is lower as the division ratio is raised, yielding lower phase noise on the lower bands. This is beneficial because on the lower-frequency bands, signals from distant stations are



much weaker relative to local stations than on the higher-frequency bands.

Elecraft uses a different approach to LO generation in their high-end K3 transceiver. Both PLL and DDS technologies are used in the design. Figure 4 shows a block diagram of the K3 synthesizer.

Figure 4: Elecraft's LO synthesizer uses both

PLL and DDS technology and a multiband software-controlled VCO for a high performance and low power.

The master frequency reference is a fixed 49.380MHz temperature-compensated crystal oscillator (TCXO). A low-power 75MHz DDS chip is used to produce the reference for the PLL, but the DDS is operated at 8.215MHz and only adjusted over a narrow range (± 2 kHz in 0.2Hz steps). The output is cleansed of any spurs by a 4-pole crystal filter that is about 1.2kHz wide. A simple PLL is used for the tunable LO, with a 3-pole active loop filter. A complex discrete VCO design is employed, with a total

Offset, kHz	TenTec Orion 2 20M	TenTec Orion 2 40M	Elecraft K3 20M	Yesu FTDX5000 20M
2.5	-128	-130	-127	-128
5	-128	-130	-127	-128
10	-128	-128	-123	-122
20	-124	-127	-120	-119
40	-118	-120	-115	-114
60	-124	-120	-110	-108
100	-122	-118	-105	-104
200	-121	-110	-102	-101
300	-120	-100	-100	-100
400	-120	-100	-100	-100
500	-120	-100	-100	-100

of 128 different L-C tank circuit combinations used, selected by software depending on the segment of the 8-46MHz tuning range.

Both approaches result in excellent phase-noise performance as shown in Table 1.

Table 1: Here is a comparison of the reciprocal mixing noise measurements for three high-performance transceivers. Three different designs yield quite different results, all of which are outstanding. (Source: Sherwood Engineering).

The K3 transceiver is a modular design, and one option is to add a complete second receiver chain, or sub-receiver. The sub-receiver can be used to listen on another frequency, or to listen on the same frequency as the main receiver, but with a separate receiving antenna favoring a different direction in an effort to reduce interference or fading. This second option is called diversity reception. In some transceivers the subreceiver is lower in performance and offers a limited version of diversity. In the K3, the subreceiver is identical to the main receiver, and LO is phase-locked to the main receiver LO, yielding true diversity reception.

Both the TenTec Orion series and the K3 use DSP for the detection and final receiver filtering. In the Orion, the first IF is at 9MHz including narrow roofing filters, a second IF is at

455kHz, and a third IF at 14kHz is delivered to a 24bit A/D converter designed for high-performance audio system. In the K3, the output of the first IF stage at 8.215MHz is mixed with a fixed 8.230MHz LO and downconverted to a 15kHz second IF. The signal here is digitized using a 24bit A/D converter, also originally developed for high-performance audio systems.

And now for something completely different Microtelecom took a different approach to receiver design in the Perseus software-defined receiver. This might be considered the brute-force digitizing method. The Perseus receiver features an extremely simple block diagram as shown in Figure 5—a front-end passive attenuator and filter, and an amplifier stage connected to a very wideband A/D converter, followed by a programmable digital downconverter (DDC) and USB interface.

Figure 5: The Perseus receiver by microtelecom uses a direct RF-sampling A/D converter and SDR architecture to eliminate analog receiver imperfections, but requires a PC and software for signal demodulation.

The DDC, implemented in an FPGA, includes a numerically-controlled local oscillator (all-digital) and a quadrature digital mixer that delivers baseband I/Q outputs at 100, 200, or 400 kbps rates to a USB interface. PC software controls the receiver and performs signal-detection and demodulation functions in the PC's processor. The performance of this complete system compares favorably with traditional all-analog and hybrid analog/DSP designs. For example, LO phase noise is virtually eliminated, since there is no LO! The only source of reciprocal mixing noise is sampling jitter in the A/D converter and phase noise in the clock oscillator, which is a fixed-frequency high-stability crystal oscillator and quite clean.

The astute reader will notice that unlike the 24bit A/D converters used on the TenTec and Elecraft radios, the Perseus only uses 14 bits of A/D converter resolution. Since a 14bit A/D converter can only provide about 86 dB of theoretical S/N ratio (and in fact the LTC2206-14A/D converter used only provides about 77 dB SNR) this would suggest that the available dynamic range of the Perseus would be much poorer than the other radios with higher A/D resolution.

However, consider that this noise, including quantization effects, and all other noise sources, is more-or-less spread out evenly across the entire bandwidth of this 80 MSPS A/D converter from dc to $F_s/2$, or 40MHz. If we are only concerned with the amount of a small slice of that bandwidth, say, 500Hz, and remove all the other noise with a digital filter, the noise present in that bandwidth is $10\log(40\text{MHz}/500\text{Hz})$, or 49 dB lower. This means that the minimum discernible signal should be $77 + 49$ dB, or 126 dB below the full scale of the A/D converter. The full-scale of the A/D converter and preamp is about -6 dBm, so the minimum discernible signal is actually -6 minus 126 or -132 dBm, which compares favorably with conventional receivers performing most of the filtering in the analog domain, and using a lower-speed, higher-resolution A/D converter at the end of the signal path.

So what's the downside to this all-digital approach? Unlike the other transceivers mentioned earlier, the Perseus requires a PC and software for operation. There is no headphone or speaker jack—the PC sound card generates the audio for the user. And it does not include a tuning knob, since tuning is done by the PC software. However, it is a great step forward in bringing SDR technology to a consumer price point, and from a technology standpoint, illustrates that SDRs can achieve performance comparable to hybrid analog/digital receiver designs.

About the author

Doug Grant received his first ham radio license from the FCC in 1967 and his BSEE in 1975. He has logged over 30 years in the semiconductor industry, mostly at Analog Devices, where he worked in engineering, marketing, and product line management for a wide range of analog, mixed-signal, RF and wireless products. He has also logged over 500,000 two-way contacts with other radio hams in every country in the world. Doug is currently an independent consultant specializing in semiconductor and wireless technologies.

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